Online-Character Recognition

Project for EQ2340 Pattern Recognition

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Introduction

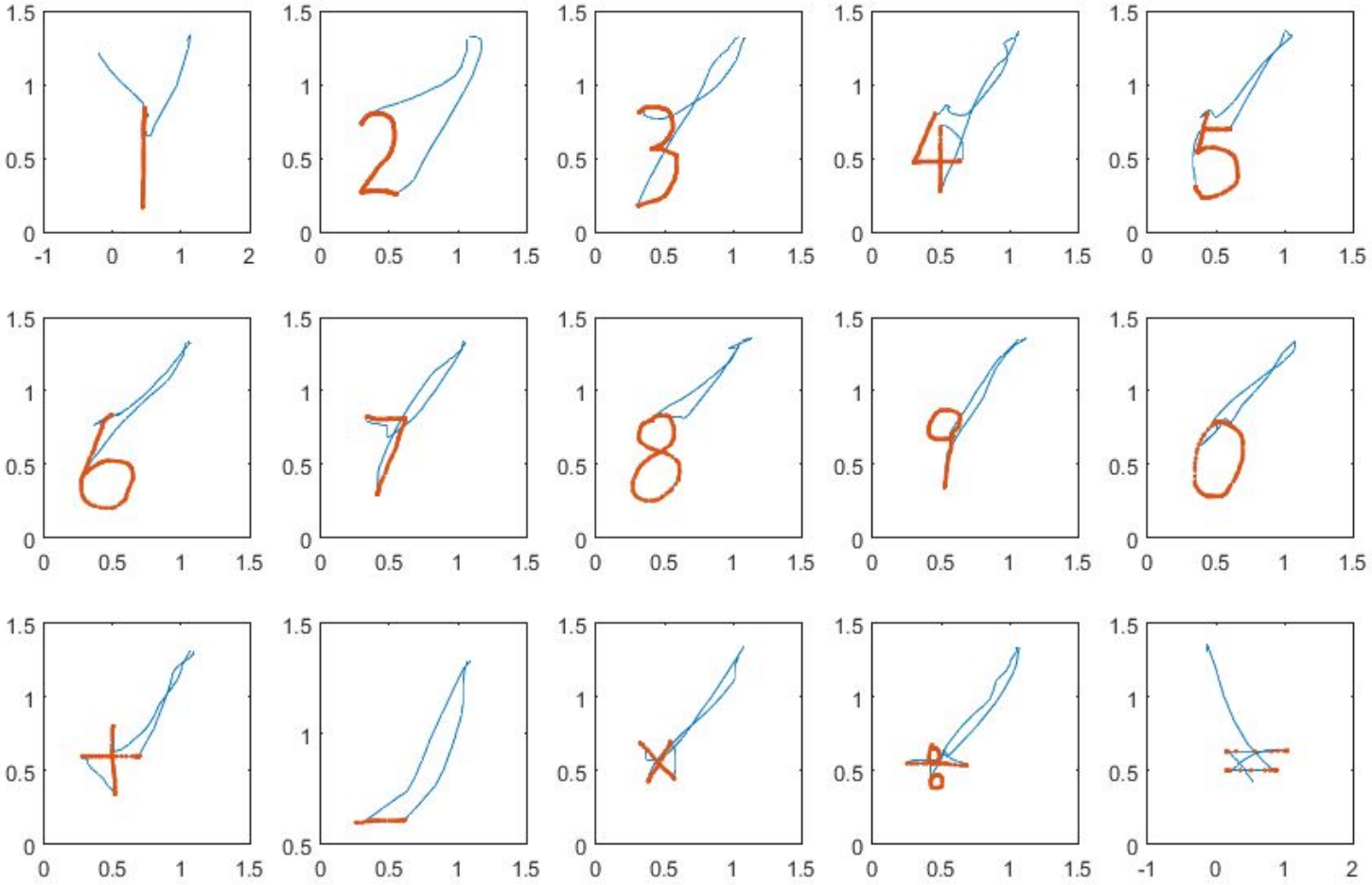
- Online-Character Recognition
- Simple Online - Handwritten Calculator
- Uses HMMs to predict Handwritten user input
- Discrete Feature Set based on pen-down directions

Dataset

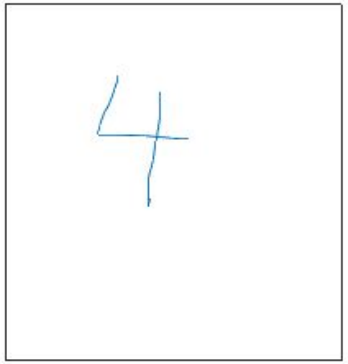
- 15 Unique Characters required for Calculator: 1~9, 0, +, -, *, /, =
- Cell array with
  - X coordinate
  - Y coordinate
  - PenUp/PenDown Binary
- Handwriting Dependent Dataset
- Diversified Dataset

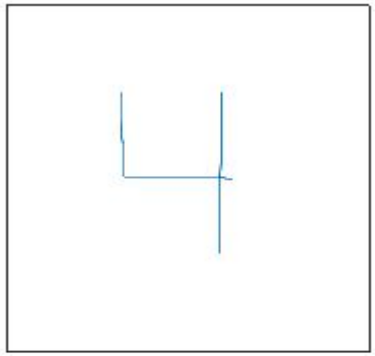
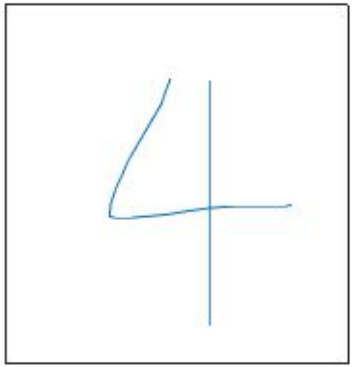
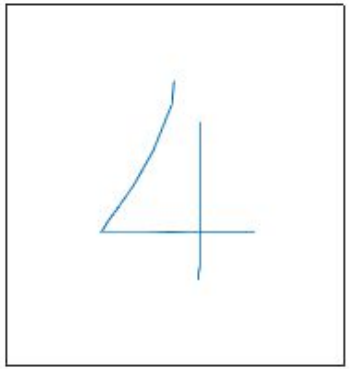
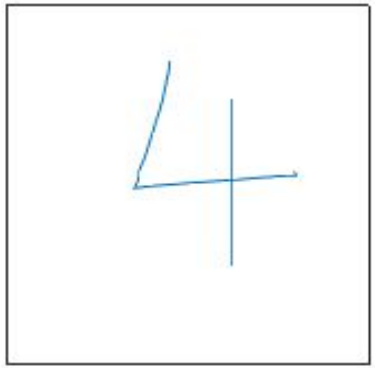
User	Handwriting Depend # per Character	Diversified # per Character
1	15	15
2	16	16
3	0	5
4	0	5
5	0	4
Total Per Character	**31**	**45**

Data Examples



Data Examples



Feature Extraction

- Feature Extraction:
  - 8 Directions
  - Pen-up/down sign

➔ 16 Discrete features indicating directions and pen-up/down

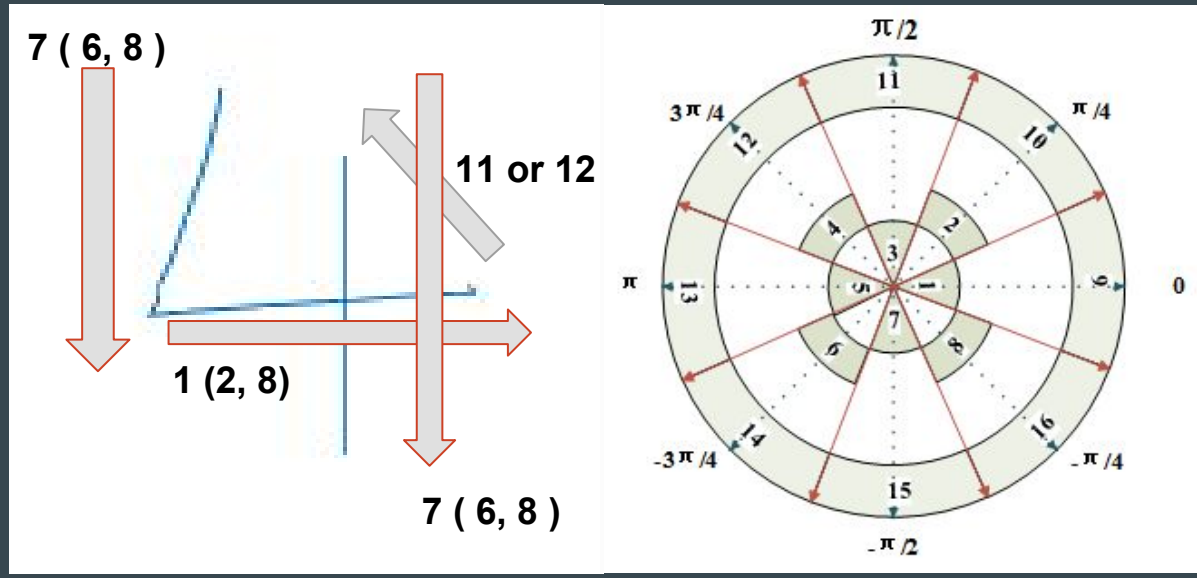


Figure. Illustration of features

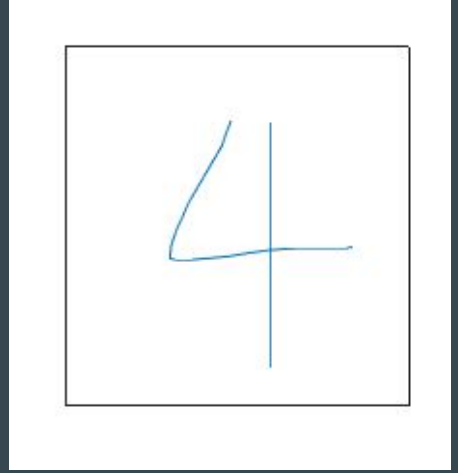
HMM Design

- **Left-Right HMM**
- 16 Discrete Features
- Test over 2~6 states, and in final version we use **5 states**.
- Initial probability vector:
  q = (1, 0, 0, 0, 0)

An example of Transition Matrix

0.8783	0.1217	0	0	0	0
0	0.3314	0.6686	0	0	0
0	0	0.8756	0.1244	0	0
0	0	0	0.3975	0.6025	0
0	0	0	0	0.9125	0.0875

Sample Feature Sequence



- Sample feature sequence of Number 4
  - 7 7 7 7 7 7 8 1 1 1 1 1 1 1 1 1
    2 2 3 12 7 7 7 7 7 7 7 7 7 7 7 8 7
- Random output sequence from trained HMM
  - HMM Trained from Small handwriting depend data:

    Emission: 7 6 7 7 7 6 8 8 8 4 1 7 1 1 1 1 12 7 7 7 3 7

    States: 1 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 4 5 5 5 5 5 6

  - HMM Trained from diversified data:

    Emission: 7 7 7 7 7 7 7 7 1 1 1 1 1 1 1 12 5 7 7 7 7 7 7

    States: 1 1 1 1 1 1 1 1 2 3 3 3 3 3 3 4 4 5 5 5 5 5 5 6

    Emission: 7 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 7 3 11
    7 7 7 7 7 7 7 7 8 7 7 7 7 7

Cross-validation

According to our size of data, **5-fold cross-validation** is chosen in our project:

- A random index is created and cut data into 5 partitions.
- Each time 4 partitions are used as training and the rest used as testing.

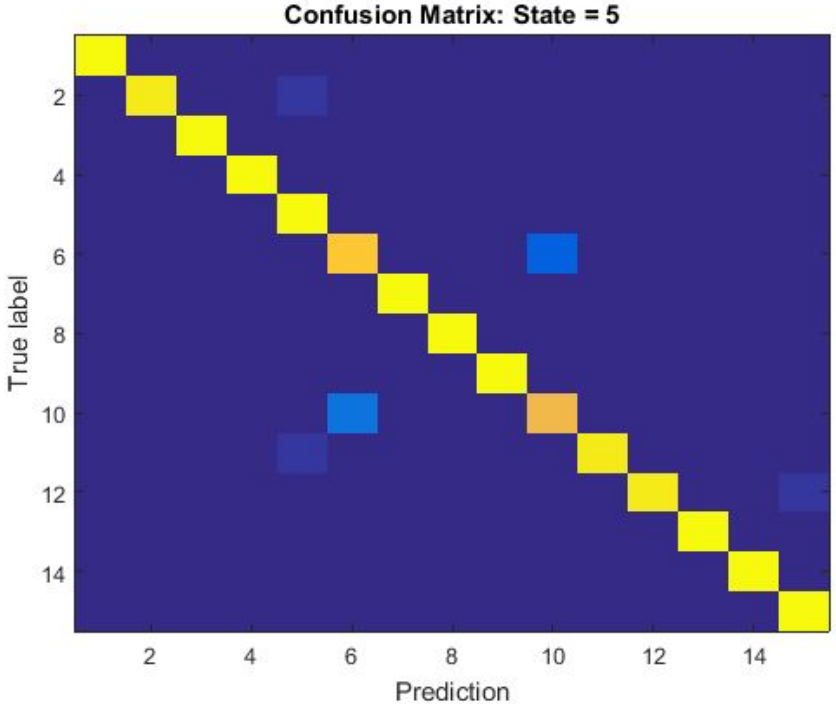
Result Analysis

- Accuracy over states:

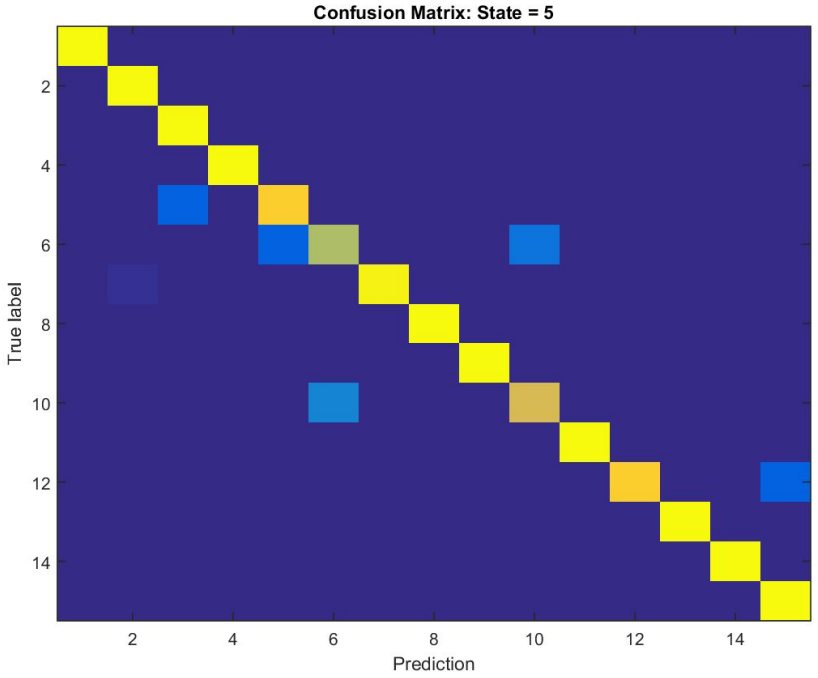
Num of States	Handwriting-dependent data	Diversified Data
2	0.94667	0.92667
3	0.97556	0.935
4	0.96667	0.93833
5	0.97111	0.94333
6	0.97556	0.94

Result Analysis - Confusion Matrix

Small Data

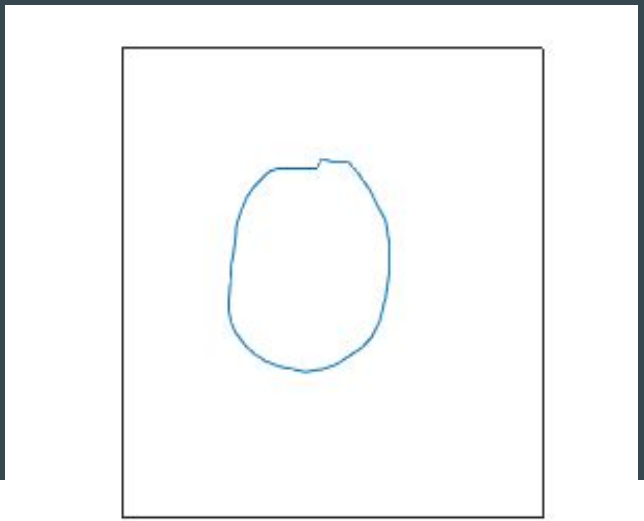


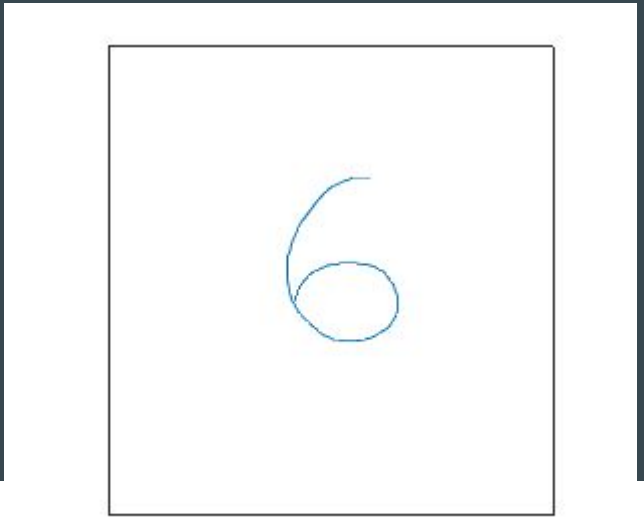
Diversified Data



Result Analysis

- Frequently misclassified samples: 6&0 (in both data)
  5->3, 6->5, '-'->'=' (in diversified data)
- Misclassified Example: 6 and 0





Calculator Demo

23 x 10+5=

Discussion

- HMM work relatively well for online Character Recognition
- Feature Design is critical
- Our design works for most cases -but there are special cases
- Classification Accuracy of at least 94% on Diversified Data
- Directions between first and last may add some improvement
- Future Work:
    - Consider Possible continuous features e.g angle sizes etc
    - Larger Dataset sets